

12

EUROPEAN PATENT APPLICATION

21 Application number: 89122999.9

51 Int. Cl.⁵: G01R 33/34

22 Date of filing: 13.12.89

30 Priority: 28.12.88 US 290950

43 Date of publication of application:
04.07.90 Bulletin 90/27

84 Designated Contracting States:
CH DE FR GB LI NL

71 Applicant: GENERAL ELECTRIC COMPANY
1 River Road
Schenectady, NY 12345(US)

72 Inventor: Liu, Yung Sheng
2201 Pineridge Court
Schenectady, New York 12309(US)
Inventor: Guida, Renato
620 Church Street
Wynantskill New York 12192(US)

74 Representative: Schüler, Horst, Dr. et al
Kaiserstrasse 69
D-6000 Frankfurt/Main 1(DE)

54 Electromagnetic transducers and method of making them.

57 A technique for fabricating a patterned conductor on the inner surface of a transparent tube comprises providing a source of conductive material inside a hollow tube and directing actinic radiation onto the tube wall where the deposition of a conductive pattern is desired to deposit conductive material thereon. That conductive deposit may be thickened by subsequent electroless or electroplating. The result is an improved magnetic resonance sensor comprising a hollow tube having "flat" conductor coils disposed on its interior surface.

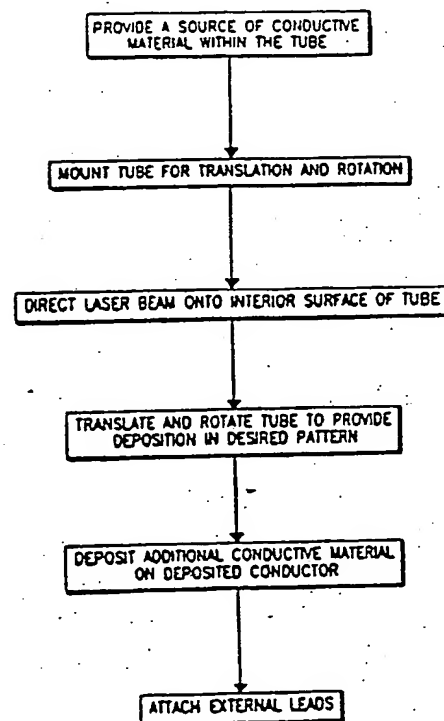


FIG. 6

EP 0 376 057 A2

ELECTROMAGNETIC TRANSDUCERS AND METHOD OF MAKING THEM

Background of the InventionField of the Invention

The present invention relates to electromagnetic transducers including conductors disposed in predetermined patterns and more particularly to patterned conductors disposed on surfaces having significant curvatures.

Prior Art

For accurate transduction of electromagnetic signals, transducers must have accurately known characteristics. Accurately known characteristics can be obtained in two different ways. The first is to fabricate individual transducers in an attempt to match a predetermined configuration, but with a fabrication tolerance which requires extensive testing to determine the actual characteristics of each transducer and whether it meets the intended specifications. The second is to fabricate the transducers with tight enough tolerances that simple testing can be used to establish that each transducer matches or fails to match the specifications for a standard transducer of the same design whose characteristics are accurately known from extensive testing. In the former case, substantial testing cost is added to the fabrication cost of each transducer thereby substantially increasing its cost. In the latter case the cost of extensive testing of the standard transducer is part of the initial development cost which is spread over all production transducers. It is generally recognized that the latter technique is preferable for both interchangeability of parts between systems and for limiting manufacturing and testing costs. Unfortunately, not all electromagnetic transducers are susceptible to fabrication to the tight tolerances necessary to enable the latter technique to be utilized. One type of transducer which has not been susceptible to being fabricated in the latter way is the pickup coil of the sensors used in magnetic resonance spectroscopy.

In magnetic resonance spectroscopy a strong uniform DC magnetic bias field is applied to a sample to be analyzed. This magnetic field causes the net spin axis of the electrons of the atoms comprising the sample to align parallel to the DC magnetic bias field. The sensor or pick-up coil has two halves and is located within this strong uniform

magnetic field with the sample being investigated disposed between the two halves. A perturbation current is passed through this sensor coil to create a magnetic field perpendicular to the DC magnetic bias field to cause the orbits of electrons in the sample material to realign with their spin no longer in the direction of the DC magnetic bias field, and preferably perpendicular to the DC magnetic bias field. The perturbation current is then removed from the sensor coil, which removes the perturbation magnetic field. The spins of the electrons then reorient back to parallel to the DC magnetic bias field. The electromagnetic signals generated by this reorientation of the electron spins are sensed by the pick-up coil and amplified and analyzed by the electronic portion of the magnetic resonance spectroscopy machine. The frequencies of the electromagnetic signals are determined by the elements and compounds present in the sample and thus provide information which can be processed to determine the composition of the sample.

For maximum accuracy in the spectrographic analysis of the material of the sample, the sensor coil must have an accurately known configuration and must be configured in a way which causes the perturbation current through the sensor coil to generate a magnetic field which is oriented perpendicular to the main DC magnetic bias field without any significant field component parallel to the main DC bias field. Further, the pickup coil itself should have no net turns through the bias magnetic field in order that the current through the coil will not alter that DC magnetic bias field.

One prior art magnetic resonance spectroscopy pick up coil is a hollow glass tube about 3/8 inch in inner diameter with a wall thickness of about 1/16 inch and having a sensor coil disposed on its outer surface. The sensor coil comprises two diametrically opposed "flat" or pancake coils which conform to the exterior surface of the tube and are connected in series. The sample to be analyzed is passed through this tube and analyzed when it is located in the tube between the two halves of the sensor coil.

The sensor coil is formed through use of photolithographic techniques to define the coil in a separate, planar, copper foil which is preferably free of all magnetic materials. The copper foil is etched to leave the coil which is then mounted on and adhered to the exterior surface of the glass tube. Mounting the coil on the tube is a labor intensive process which is subject to significant variation even with the exercise of great care by the operator. As a result, sensor coils of this type must be extensively and carefully quality control

tested prior to being accepted for shipment, sale and use as a sensor coils. Both the manual fabrication process and the extensive testing it makes necessary contribute significantly to the cost of such sensor coils. Since the basic material costs are minimal, the fabrication process and testing are the primary contributors to the cost.

Improved and less expensive coil designs and fabrication techniques are desirable.

Accordingly, it is an object of the present invention to provide a method of fabricating a magnetic resonance sensor which is accurately reproducible whereby the need for extensive testing is obviated.

It is also an object of the invention is to provide a magnetic resonance sensor fabrication technique which is inexpensive in order that the cost of such sensors may be reduced.

An additional object of the invention is to provide a technique for fabricating precision conductor patterns on surfaces having significant curvature.

Another object of the invention is to provide a technique for fabricating precision patterned conductors on the surfaces of a cylindrical object.

Another object of the invention is to provide a technique for fabricating precision patterned conductors on the interior surface of a hollow tube, which may be transparent.

A further object of the invention is to provide an improved magnetic resonance sensor.

A still further object of the invention is to provide a magnetic resonance sensor having improved sensitivity and accuracy.

A still further object of the invention is to provide a magnetic resonance sensor in which the pick up coils are immediately adjacent to the sample volume being investigated.

Summary of the Invention

In accordance with the present invention, the above objects are accomplished through photoreactive control of the patterning of a conductor on a surface having significant curvature. In accordance with one embodiment of this technique, a patterned conductor is provided on the interior surface of a hollow tubular member which is transparent to a photoreactive wavelength of light. The reactive light is focussed through the wall of the tubular member onto the interior surface of that wall in order to induce or catalyze the deposition of conductive material on those portions of the inner surface onto which the light is focussed while a source material for the conductive material being deposited is present in the vicinity of that focussed light. The pattern of the conductor is determined by

relative movement between the focussed light and the tube. A thicker conductive layer may be obtained by subsequently depositing additional conductive material on top of the photoreactively deposited material. Other patterning techniques may also be used.

An improved magnetic resonance sensor is provided in the form of a hollow tubular member which confines the sample during evaluation and has the magnetic resonance sensor coils disposed on its interior surface. These coils may have more turns than prior art coils, which increases their sensitivity.

Brief Description of the Drawings

The features of the invention believed to be novel are set forth with particularity in the appended claims. The invention itself, however, both as to organization and method of operation, together with further objects and advantages thereof, may best be understood by reference to the following description taken in conjunction with the accompanying drawing(s) in which:

Figure 1 illustrates, in perspective view, a prior art magnetic resonance sensor;

Figure 2 illustrates, in plan view, a prior art sensor coil prior to its application to the tube;

Figure 3 illustrates, in partially cut away, perspective view, a magnetic resonance sensor in accordance with the present invention;

Figure 4 illustrates, in perspective view, an alternative pattern for a conductor disposed on the interior surface of a hollow tubular member;

Figure 5 illustrates in partially perspective, partially block diagram form, an apparatus for fabricating transducers in accordance with the present invention; and

Figure 6 illustrates a process of fabricating transducers in accordance with the present invention.

Detailed Description of the Invention

A state of the prior art magnetic resonance sensor for use in spectroscopy is illustrated in Figure 1. The sensor 10 comprises a hollow glass tube 12 having an exterior surface 14 and an interior surface 16. For magnetic resonance spectroscopy, this tube is typically less than an inch in diameter and may have an inner diameter of about 3/8 inch. A conductor pattern 20 is disposed on exterior surface 14 of the tube 12. The pattern 20 comprises two "flat" coils 22 which are connected

in series and have external leads 24 and 26 connected to opposing ends of the conductor. In accordance with the prior art fabrication techniques, the conductor pattern is initially formed by photolithographic processing of a copper foil to provide the conductor 20 in its flat coil form as shown in Figure 2. Bridge connectors 28 are included in the etched pattern of the foil in order to hold the coil pieces in their desired relative positions during assembly. The coils 22 are assembled on the tube 12 in diametrically opposed positions to form the sensor 10 of Figure 1. One assembly process involves applying a layer of epoxy to the exterior surface of the tube where the coil is to be located, laying the coil in place and allowing the epoxy to cure. Thereafter, the copper tabs or bridges 28, shown in Figure 2, are cut and removed to leave the desired coil shape on the glass tube as shown in Figure 1. This process is labor intensive, requires pains-taking, skilled manipulation of small parts, and results in sensor-to-sensor variations as a result of coil-to-coil variations in shape and placement. Substantial testing is required to insure that a given sensor 10 meets specifications before that sensor can be accepted for use. The sample to be analyzed by magnetic resonance spectroscopy is passed through the tube 12 and either held stationary or moved at a known rate during analysis. The sample is analyzed when it is located between the two halves of the pickup coil.

A magnetic resonance sensor 100 in accordance with the present invention is illustrated in Figure 3. The sensor 100 comprises a glass tube 112 having an outer surface 114 and an inner surface 116. A conductive pattern 120 is disposed on the inner surface 116 of tube 112. The pattern 120 consists of two coils 122 connected in series, each of which comprises a plurality of oblong turns whose long sides run parallel to the axis of the tube, and which are situated diametrically opposite each other. The conductor 120 has first and second external leads 124 and 126. The leads 124 and 126 preferably are attached to the exterior surface 114 of the tube and extend through holes 118 in the tube wall into the interior of the tube. The holes 118 may be laser-drilled or fabricated in other ways. The connection from the winding 122 on the inside surface 116 to the external leads 124 and 126 may be via through-plating on the holes 118, via eyelets inserted in the holes, or by other appropriate means.

In accordance with the methods of fabrication to be described hereinafter, the sensor 100 is accurately reproducible with the result that minimal testing is required to ensure that a given sensor 100 meets specifications. In particular, the problems of misorientation and variations in the shape of and spacings between adjacent turns of the

winding are eliminated by the method of fabrication, with the result that once an acceptable configuration for the sensor 100 and its conductive pattern 120 has been determined and produced, concerns about sensor-to-sensor variations in coil position, spacing and orientation are eliminated. As a result, simple testing is sufficient to certify that the sensor meets specifications.

While the conductive pattern 120 is described and shown as being disposed on the inner surface 116 of the tube 112, it will be understood that although that is preferred, the patterned conductor may be disposed on the exterior surface 114 if desired. Such exterior placement increases the spacing between the sample and the coil, which reduced sensitivity and is therefore considered less desirable than interior placement. However, external placement is feasible where the difference in sensitivity is considered acceptable. Exterior placement of this coil still provides substantial improvement over prior art sensors 10 because of the increased number of turns which may be provided in the inventive coil and because of the increased precision with which the inventive coil is fabricated. This precision minimizes the quantity of testing necessary to certify that the sensor meets specifications and also substantially eliminates the problem of rejection of finished sensors as not meeting specifications, thereby increasing yield and reducing costs.

The method of this invention may be utilized to produce many different conductor patterns on the surface of a tube or other structure having a significant curvature to its surface. One such alternative pattern is shown in Figure 4 where a transducer 200 comprises a tube 212 having an exterior surface 214 and an interior surface 216. A patterned conductor 220 is disposed on the interior surface 216 of the tube 212. The conductor 220 is in the form of a single helical spiral 222 having a first external lead 224 connected to one end and a second external lead 226 connected to its other end. Leads 224 and 226 are preferably connected to conductor 220 via through holes in the tubing wall. The transducer 200 is suitable for producing or responding to magnetic fields which run axially of the tube 212.

Many variations on the conductor pattern are possible. These include, but are not limited to, a plurality of parallel conductors, which may be helical, for example, or a plurality of conductors connected in common at one or both ends, and so forth. In accordance with the invention, almost any conductive pattern can be created, so long as it does not involve crossovers in which the second conductor to be defined would be shadowed by the first conductor deposited. The problem of shadowing can be overcome by projecting the laser light

through the tube wall on which shadowing does not occur and through the gas within the tube to focus on the tube wall on which shadowing does occur. Naturally, if crossing conductors are to be insulated from each other and are disposed on the same wall surface, an insulating layer must be applied before the second conductor is deposited.

The sensor 100 is preferably fabricated by the method illustrated in Figure 6 using the apparatus shown schematically in Figure 5.

The first step in the process is providing in the tube 112 a material which will deposit a conductor on the wall of the tube where the photochemically active or actinic light is focused. For example, tungsten hexafluoride (WF_6) mixed with hydrogen gas at a pressure of about 100 Torr has been used as this material in order to deposit tungsten on the tube wall, but many other materials may be used. The ends of the tube are preferably closed with plugs to contain the desired gas and to exclude undesirable gases. The terms photoreactive light, reactive light, photochemically active light and actinic light are used interchangeably in this specification and are used herein in the broad sense of producing a physical effect or change in or of material which is exposed to it. This may involve a chemical change, evaporation, sublimation, delamination or any other physical change in accordance with the circumstances.

The second step is mounting the tube 112 in a deposition system 70 which includes manipulation or drive apparatus 72 which is capable of rotating the tube about its longitudinal axis 113 and translating the tube parallel to its longitudinal axis.

The third step is positioning and focusing a laser 74 which is preferably a continuous wave (CW) laser to direct its emissions on the tube 112. A focusing objective 76 is adjusted to focus the laser's beam on the interior surface of the tube which is closest to the laser source. A shutter 78 may be used to interrupt the laser beam. The entire system operates under the control of a control unit 80, or may be manually operated. A laser having an emission spectrum which is photochemically active is selected in accordance with the deposition process being used. Focusing of the laser may be accomplished before the tube is positioned or while the laser is directed at a portion of the tube 112 which is spaced from the desired location of the conductive pattern or it may be done while the laser is directed at a portion of the area where the conductive pattern is to be disposed.

Fourth, the laser is turned on and drive 72 rotates and translates tube 112 in a pattern to cause the focused laser beam to trace, on the interior surface 116 of the tube, the desired pattern of the conductive layer 120 which, in the example

given, comprises tungsten. The laser light may be interrupted by shutter 78 or by turning off the laser power at those times when it is desired to skip from one point to another without depositing a conductive trace. With an argon laser Model 2025-05 made by Spectra Physics, operating at a power level of 50 mW, a translation rate of up to 1 mm per second has been found to produce a continuous conductive trace with the specified gaseous source material. Other source material pressures and other source materials may enable or require different tracing rates. The minimum conductive trace width is determined by the focus of the laser. Thus, in this example, when the laser was focused to a spot of about 30 microns in diameter, a trace about 20 microns wide resulted. Defocusing the laser to a spot size of about 100 microns resulted in a conductive trace having a width of about 60 microns.

Fifth, for any of the conductive patterns where a high conductivity is desired for the pattern, additional conductive material may be deposited on the initial laser-induced deposit, such as by electroless plating or electroplating, to make the initial deposit thicker, more conductive and capable of carrying larger currents. Such plating can also provide a substantial reduction in the resistance of the winding. This is particularly true where the initially deposited conductive material has a relatively high resistance as compared to the subsequently deposited material which may be a material such as electroplated copper which has a substantially higher conductivity than tungsten.

Sixth, the external leads are attached to the ends of the coil. Alternatively, the external leads may be attached before laser deposition or before the thickening deposition.

The source material in the foregoing process may be a liquid or a solid instead of a gas at the time of exposure. For example, a solution of palladium acetate in chloroform was prepared and the interior of the tube coated with that solution by immersing the tube in the solution. The coating was air dried and then exposed to actinic radiation, as discussed above, to deposit palladium in the desired conductor pattern. The unexposed palladium acetate and the residues from the exposed palladium acetate were then removed by rinsing the tube in chloroform. Copper was then deposited on the palladium using an electroless copper deposition process in which the palladium catalyzed the deposition of the copper.

This same process can be performed using the palladium acetate in chloroform solution as a liquid source of the palladium by filling the tube with that solution and then illuminating the tube in the desired pattern as heretofore described. In filling the tube with a liquid source, pressure relief should be

provided to ensure that any subsequent heating of the liquid by the laser beam will not result in an explosion or other damage to the tube, apparatus or operator.

Useful source materials include, but are not limited to carbonyl, alkyl, halide and hydrogen compounds of elements such as tungsten, zinc, aluminum, molybdenum, platinum, palladium, copper, gold and silicon. Any compound containing a metallic element whose deposition can be induced by light may be used as a source material.

Many alternative methods may be used to produce coils in accordance with the present invention. For example, a continuous conductive film may be deposited on the interior surface of the tube and the laser then focused through the tube wall onto the interface between the conductive layer and the glass with sufficient power applied to cause the conductive layer to sublime, evaporate or otherwise evolve or separate from the surface in a pattern which leaves the conductor only in those locations which correspond to a predetermined pattern.

In another alternative embodiment, a layer of photoresist, such as Fanton™ photoresists available from Armstrong World Industries, Inc., may be deposited on the interior surface of the tube, exposed by laser tracing through the tube wall and then developed to leave the photoresist on the interior surface of the tube in the negative of the desired conductor pattern. This tracing may be executed using the same apparatus (shown in Figure 5) as that used for the direct deposition of conductive material from a gas as has been described. Fanton photoresist is presently preferred for this use because its exposure is much less sensitive to its thickness than other photoresists are. The conductor may then be deposited over the photoresist and the photoresist removed to lift off the conductor except where the conductor is directly disposed on the tube surface.

As a further alternative, a continuous conductive film may be formed on the interior surface of the tube and the Fanton resist deposited over the conductive film. The resist is then exposed using laser light directed onto the photoresist from the interior of the tube. While a variety of means may be used for directing this laser light, optical fibers are suitable small in diameter and capable of carrying sufficient light intensity to expose the photoresist in accordance with a tracing of the spot on the surface. Thereafter the photoresist is developed, the deposited conductor is etched or otherwise removed where the photoresist has been removed, and then the remaining or protective portion of the photoresist is removed to leave the desired conductor pattern on the interior of the tube surface. This conductor pattern may also be thickened by

electroless or electroplating or other deposition as desired.

While the discussion thus far has been in terms of conductor patterns disposed on the interior surface of the glass tube, similar conductor patterns may be provided on the exterior surface of the tube with the same precision and repeatability benefits as have been described for the interior placement of the conductor pattern.

While only certain preferred features of the invention have been illustrated and described herein, many modifications and changes will occur to those skilled in the art. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit of the invention.

Claims

1. In combination:

a tubular member having a tubular axis, an inner surface, and a length parallel to its tubular axis; and a patterned conductor comprising a coil disposed on said inner surface.

2. The combination recited in claim 1 wherein: said tubular member has an inner diameter of less than 1 inch.

3. The combination recited in claim 1 wherein: said tubular member is comprised of an electrically insulating material.

4. The combination recited in claim 1 wherein: said tubular member is comprised in part of an electrically conductive material and includes an electrically insulating material comprising the inner surface of said tubular member at least in those portions on which the patterned conductor is disposed.

5. The combination recited in claim 1 wherein said tubular member is comprised of a material which is intrinsically transparent to at least some actinic wavelengths of light.

6. The combination recited in claim 1 wherein: said tubular member consists of nonmagnetic material.

7. The combination recited in claim 1 wherein said coil is helical with a coil axis thereof disposed parallel to said tubular axis.

8. The combination recited in claim 7 wherein said coil has a coil axis disposed substantially perpendicular to said tubular axis.

9. The combination recited in claim 1 wherein: said patterned conductor comprises two coils having their centers on opposing sides of the volume enclosed by said inner surface of said tubular member.

10. The combination recited in claim 9 wherein said two coils are disposed on a common coil axis

which intersects said tubular axis.

11. The combination recited in claim 9 wherein said two coils are connected in series.

12. The combination recited in claim 1 wherein said patterned conductor has different compositions adjacent said inner surface and remote from said inner surface.

13. The invention recited in claim 12 wherein said patterned conductor includes an initial layer comprised of a material selected from the group consisting of tungsten, zinc, aluminum, molybdenum, platinum, palladium, copper, gold and silicon disposed on said interior surface of said tube.

14. The invention recited in claim 13 wherein said patterned conductor includes a further layer of conductive material selected from the group consisting of copper and gold, disposed on and in intimate contact with said initial layer.

15. In combination:
a tubular member having an inner surface, an outer surface and a length parallel to its tubular axis; and a patterned conductor deposited on said outer surface, said patterned conductor having different compositions adjacent to and remote from said outer surface of said tubular member.

16. The combination recited in claim 15 wherein:

said patterned conductor comprises a coil.

17. The combination recited in claim 15 wherein:

said patterned conductor comprises two coils having their centers disposed on opposing sides of said tubular member.

18. The combination recited in claim 17 wherein:

said two coils share a common coil axis which is disposed substantially perpendicular to said tubular axis.

19. A method of forming a desired conductor pattern on the inner surface of a hollow tubular member comprising:

providing said hollow tubular member;
providing within said hollow tubular member a source of a conductive material to be deposited on said inner surface of said tubular member;
providing a source of photochemically active light having a wavelength which is capable of causing said conductive material to deposit from said source material onto said inner surface of said tubular member; and

directing said light onto said inner surface in a pattern corresponding to said desired conductor pattern to cause deposition of said conductive material from said source material onto said inner surface where said light strikes said inner surface.

20. The method recited in claim 19 wherein:
the step of providing a source material comprises providing a fluid source material.

21. The method recited in claim 20 wherein said fluid source material comprises a compound of a metallic element.

22. The method recited in claim 21 wherein said metallic element is selected from the group consisting of tungsten, zinc, aluminum, molybdenum, platinum, palladium, copper, gold and silicon.

23. The method recited in claim 19 wherein:
the step of providing a source material comprises providing a gaseous source material.

24. The method recited in claim 20 further comprising, after the directing step:
increasing the thickness of the patterned conductor by depositing additional conductive material on said patterned conductor.

25. A method of forming a patterned conductor on the inner surface of a hollow tubular member comprising:

providing said hollow tubular member;
forming a continuous layer of conductive material on at least a portion of the inner surface of said hollow tubular member; and
selectively removing portions of said continuous layer of conductive material from said inner surface of said tubular member to leave a predetermined pattern of conductive material on the inner surface of said tubular member.

26. The method recited in claim 25 wherein the removing step comprises:

providing a source of light; and
directing the light from said source on the portions of said continuous layer of conductive material which it is desired to remove in an intensity and for a time sufficient to cause the conductive material illuminated thereby to separate from said inner surface of said tubular member and from the portions of said conductive layer which were not exposed to said light.

27. The method recited in claim 25 wherein the light from said source is directed onto said layer in the form of a small spot and wherein said method further comprises moving said spot relative to said tubular member in a pattern which traces the area from which conductive material is to be removed.

28. The method recited in claim 26 wherein said tubular member is transparent to said light and said light is directed through the thickness of the wall of said tubular member onto the surface of the conductive layer which is in contact with said wall.

29. The method recited in claim 28 wherein said light is directed onto said conductive layer from within the hollow interior of said hollow tubular member.

30. The method recited in claim 28 wherein the directing step comprises passing said light through an optical transmission system which extends into the hollow interior of said tubular member.

31. The method recited in claim 30 wherein the

step of passing said light through an optical transmission system comprises passing said light through a fiber optic transmission system.

32. The method recited in claim 26 wherein the step of providing a source of light comprises providing a laser having a wavelength suitable for performing the selectively removing step.

33. The method recited in claim 25 wherein the selectively removing step comprises:

depositing a layer of photoresist over said conductive layer in the interior of said hollow tubular member;

exposing and developing said photoresist in a pattern corresponding to said desired conductor pattern; and

removing the portions of said conductive layer which are not protected by said photoresist.

34. The method recited in claim 33 further comprising, after the step of removing the unprotected conductive material:

removing the remaining portions of said photoresist layer from the remaining portions of said conductive layer.

35. The method recited in claim 34 further comprising after the step of removing said remaining portions of said photoresist layer:

increasing the thickness of said conductive pattern by depositing additional conductive material onto the remaining portions of said conductive layer.

36. The method recited in claim 32 wherein the step of depositing said photoresist layer comprises depositing a layer of Fenton photoresist.

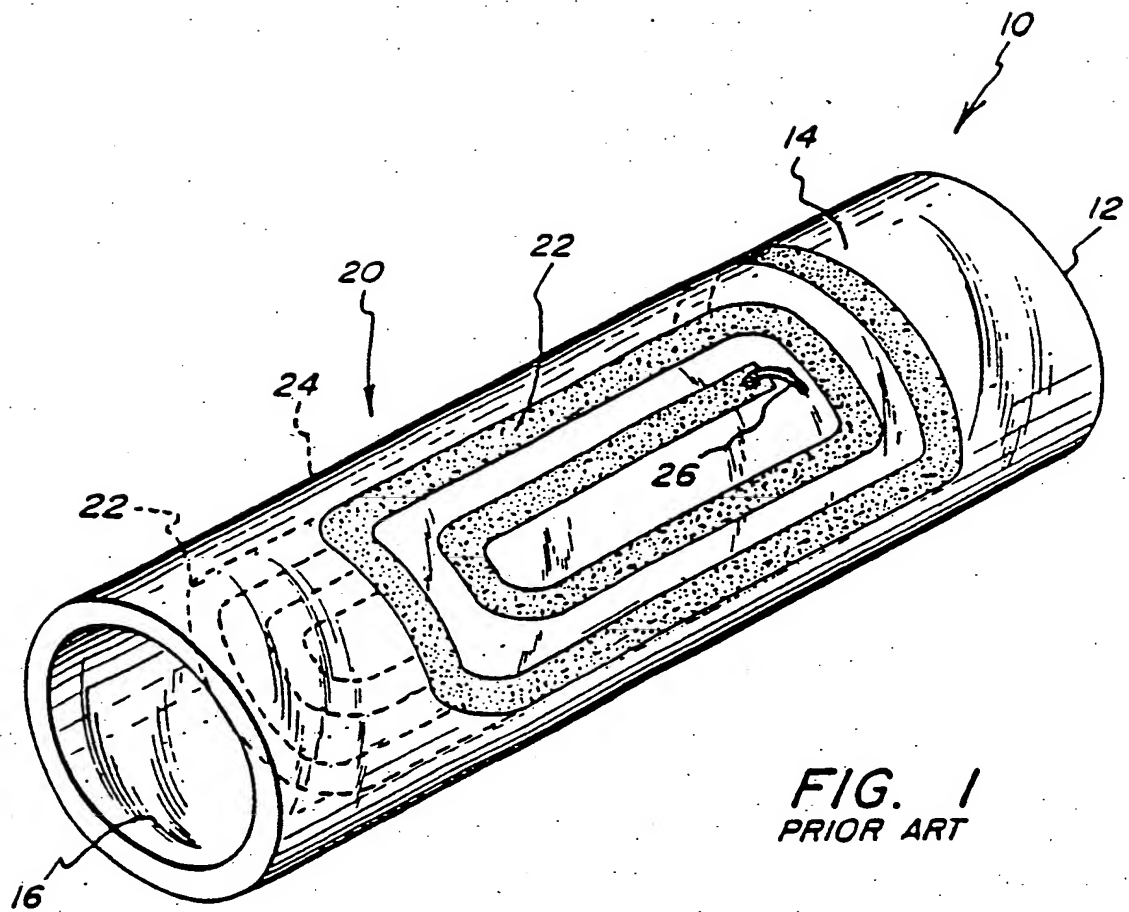


FIG. 1
PRIOR ART

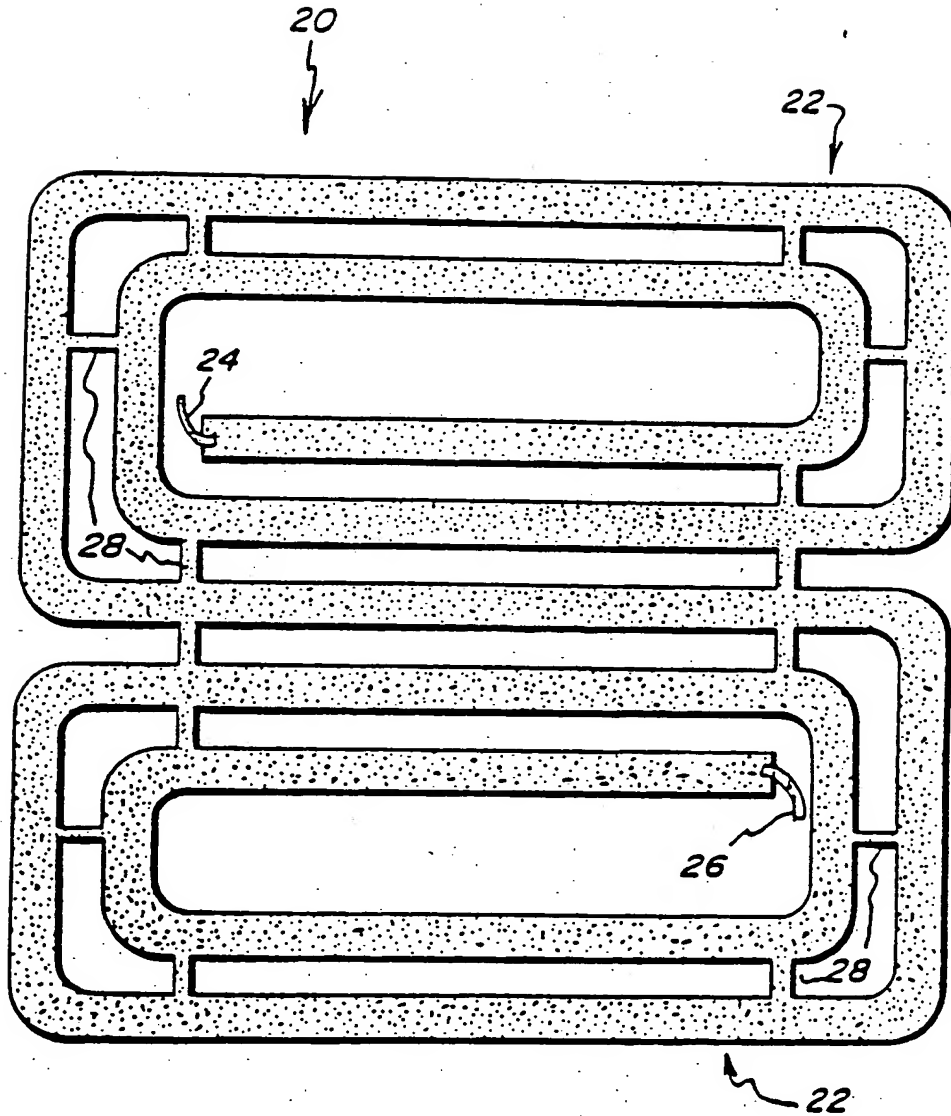


FIG. 2
PRIOR ART

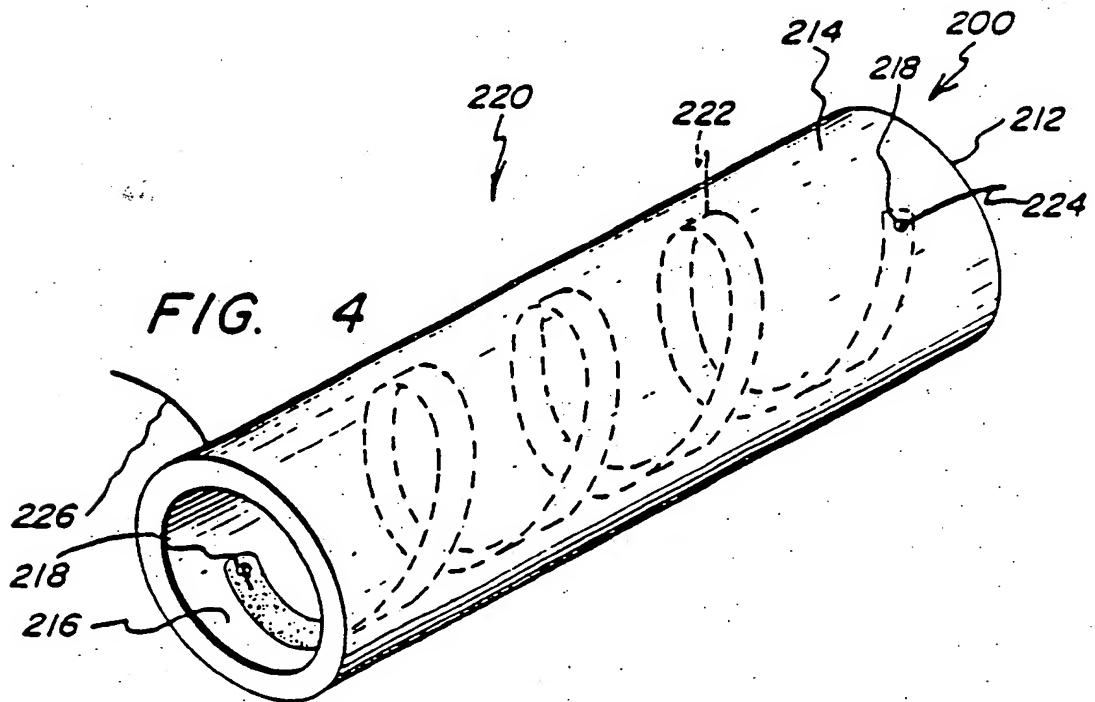
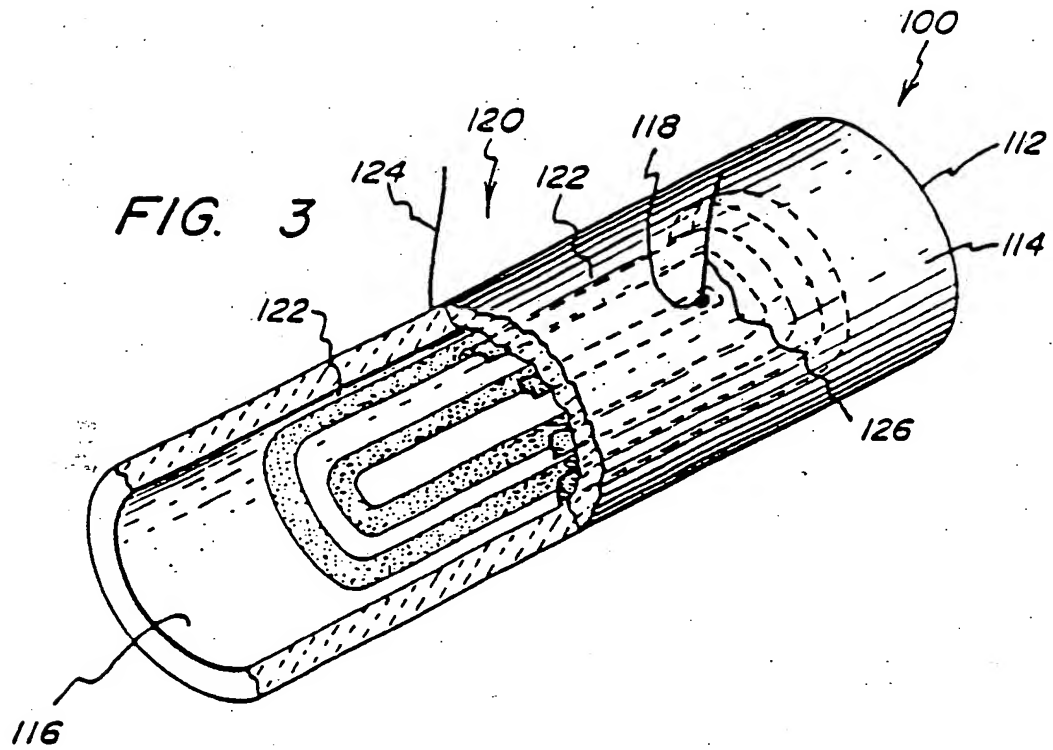
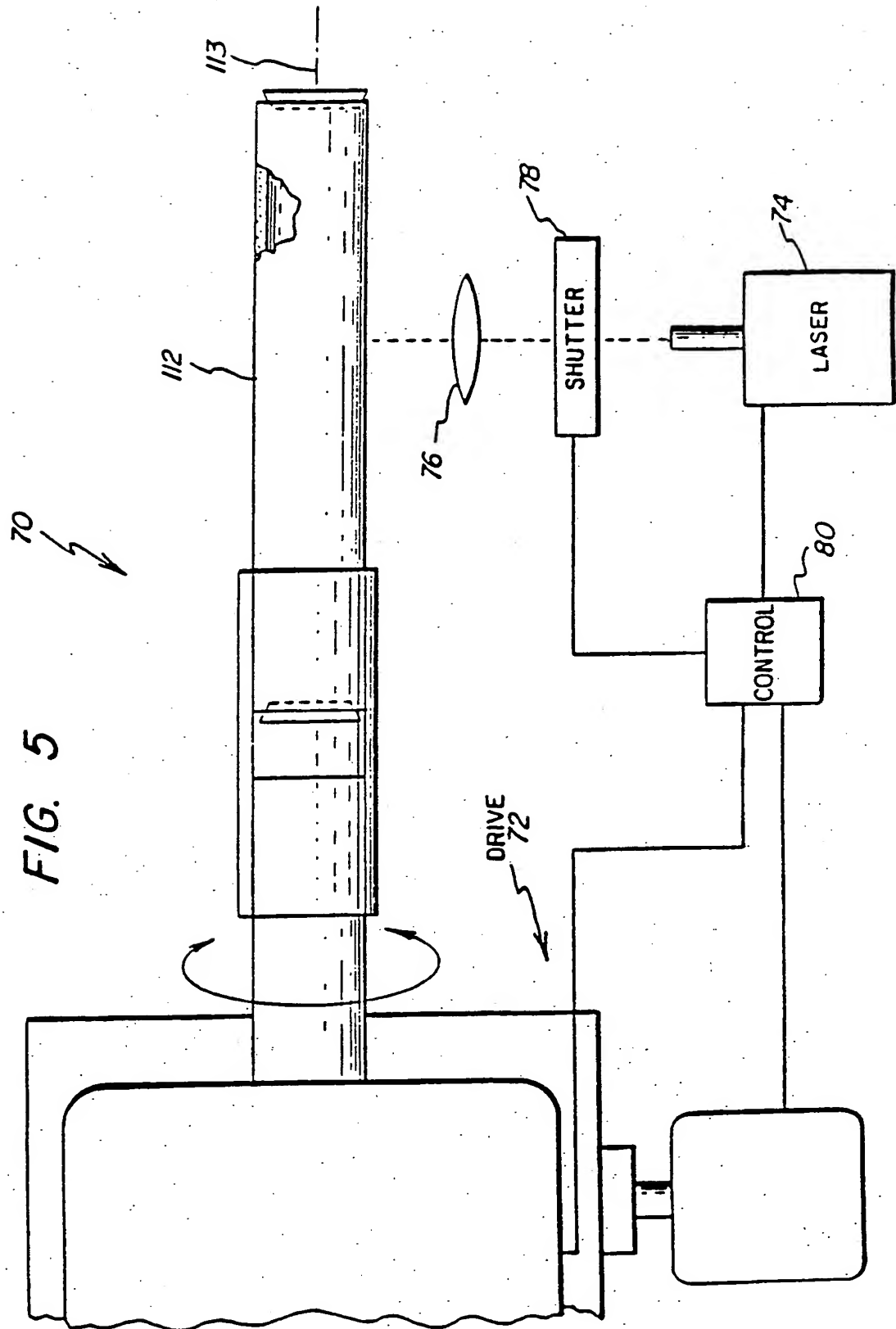


FIG. 5



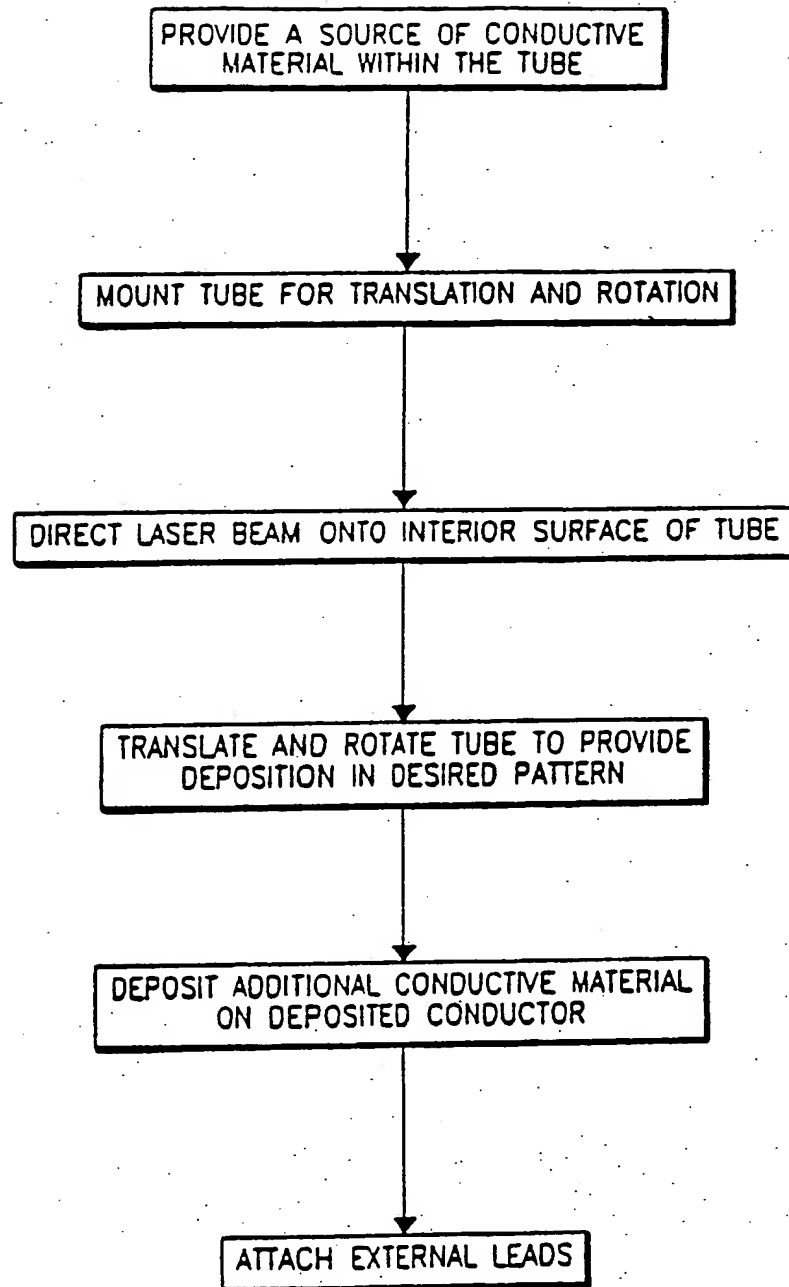


FIG. 6



Europäisches Patentamt
European Patent Office
Office européen des brevets



(11) Publication number:

0 376 057 A3

(12)

EUROPEAN PATENT APPLICATION

(21) Application number: 89122999.9

(51) Int. Cl.⁵ **G01R 33/34**

(22) Date of filing: 13.12.89

(30) Priority: 28.12.88 US 290950

(43) Date of publication of application:
04.07.90 Bulletin 90/27

(84) Designated Contracting States:
CH DE FR GB LI NL

(98) Date of deferred publication of the search report:
12.06.91 Bulletin 91/24

(71) Applicant: **GENERAL ELECTRIC COMPANY**
1 River Road

Schenectady, NY 12345(US)

(72) Inventor: **Liu, Yung Sheng**
2201 Pineridge Court
Schenectady, New York 12309(US)
Inventor: **Guida, Renato**
620 Church Street
Wynantskill New York 12192(US)

(74) Representative: **Schüler, Horst, Dr. et al**
Kaiserstrasse 69
W-6000 Frankfurt/Main 1(DE)

(54) Electromagnetic transducers and method of making them.

(57) A technique for fabricating a patterned conductor on the inner surface of a transparent tube comprises providing a source of conductive material inside a hollow tube and directing actinic radiation onto the tube wall where the deposition of a conductive pattern is desired to deposit conductive material thereon. That conductive deposit may be thickened by subsequent electroless or electroplating. The result is an improved magnetic resonance sensor comprising a hollow tube having "flat" conductor coils disposed on its interior surface.

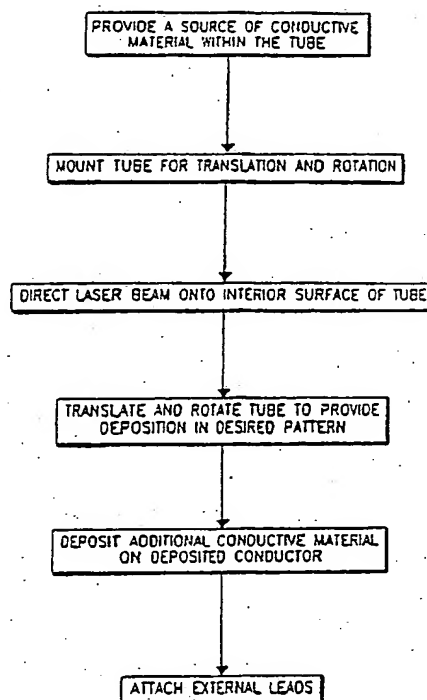


FIG. 6

EP 0 376 057 A3



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number

EP 89 12 2999

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	US-A-3 769 698 (E.E. LADEMANN et al.) * Column 1, lines 21-55; column 2, line 12 - column 3, line 2; figures 5,6 *	1,3,6	G 01 R 33/34
A	---	9-11,25	
X	GB-A-2 094 482 (VARIAN ASSOCIATES INC.) * Page 1, lines 47-72; page 1, line 96 - page 2, line 57; figure 3 *	1,3,6,9-11	
A	---	25	
A	PATENT ABSTRACTS OF JAPAN, vol. 5, no. 173 (P-87)[845], 5th November 1981; & JP-A-56 101 543 (NIPPON DENSHI K.K.) 14-08-1981 * The whole abstract *	1,3,6,9,10,15-18	
A	GB-A-2 151 791 (GENERAL ELECTRIC CO.) * Page 1, line 53 - page 3, line 19; figures 1a,b *	15,17,18,25	
A	IBM TECHNICAL DISCLOSURE BULLETIN, vol. 17, no. 7, December 1974, page 2113, New York, US; J. BARGON et al.: "Manufacturing coils and shields" * The whole article *	25,33-35	TECHNICAL FIELDS SEARCHED (Int. Cl.5) G 01 R H 01 F
A	PATENT ABSTRACTS OF JAPAN, vol. 10, no. 263 (E-435)[2319], 9th September 1986; & JP-A-61 88510 (JEOL LTD) 06-05-1986 -----	1,15,19-21,23	
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 04-03-1991	Examiner VOLMER J.W.
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons ----- & : member of the same patent family, corresponding document			

**This Page is Inserted by IFW Indexing and Scanning
Operations and is not part of the Official Record**

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- ☐ **BLACK BORDERS**
- ☐ **IMAGE CUT OFF AT TOP, BOTTOM OR SIDES**
- ☐ **FADED TEXT OR DRAWING**
- ☐ **BLURRED OR ILLEGIBLE TEXT OR DRAWING**
- ☐ **SKEWED/SLANTED IMAGES**
- ☐ **COLOR OR BLACK AND WHITE PHOTOGRAPHS**
- ☐ **GRAY SCALE DOCUMENTS**
- ☐ **LINES OR MARKS ON ORIGINAL DOCUMENT**
- ☐ **REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY**
- ☐ **OTHER:** _____

IMAGES ARE BEST AVAILABLE COPY.

As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.